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Growth and development of *Dalbergia sissoo* and *Acacia nilotica* under Salinity

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ABSTRACT

Salinity toxicity normally results when certain ions are taken up with the soil- water and accumulate in the leaves during water transpiration to an extent that result in damage to the plant. The degree of damage depends upon time, concentration, crop sensitivity and crop water used, and if damage is severe enough, crop yield is reduced. The usual toxic ions in irrigation water are chloride, sodium and boron. Damage can be caused by each, individually or in combination. In India growth responses of Dalbergia sissoo and Acacia nilotica seedlings on different levels of soil sodicity and salinity. The growth and dry weight of one-year old seedlings decreased as the level of sodicity and salinity increased in both species. However, the suppression in growth caused by sodicity and salinity was relatively greater in D. sissoo than in A. nilotica. A. nilotica showed wider response breadth compared with D. sissoo on both the gradients. Further, the response breadths were comparatively higher under sodicity levels than under salinity levels. Dalbergia sissoo in its natural and man-influenced ecosystem was being adversely affected by various abiotic stresses. Studies undertaken on the physio-chemical characteristics of soil under dead and healthy trees of Dalbergia sissoo and to correlate soil factors with the decline of shisham in semi-arid regions revealed that the pH, ECe, bulk density and calcium carbonate was found higher in soil under dead trees as compared to healthy trees. The value increased with increase in soil depth. The organic carbon and macro-nutrient (i.e. N, P, K, Ca, Mg and S) and micro-nutrients (Zn, Fe, Cu, and Mn) were higher under healthy trees as compared to dead trees and their concentrations decreased with increase in soil depth both in case of healthy as well as dead trees of Dalbergia sissoo.

Key words: *Acacia nilotica, Dalbergia sissoo, Growth, Mortality and Salinity*

INTRODUCTION

For the past hundreds of year's trees like *Dalbergia sissoo* (shisham), *Acacia nilotica* (Kikar), *Prosopis cinneraria* (Khejri) etc. have inhabited vast areas in the plains of Afghanistan, Pakistan, India, Nepal and Myanmar. These have also been widely used for afforestation in many parts of the country except in the very hot, cold and wet tracts. These have good atmospheric N_{2}- fixing ability, therefore, are extensively planted in social and agro-forestry programmes.

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However, the past few decades have seen a strange phenomenon of tree mortality in the northern part of the Indian sub-continent comprising of Uttar Pradesh, Haryana, Punjab, Rajasthan, parts of Himachal Pradesh and even adjoining Pakistan, Nepal and Myanmar. Changing environmental conditions including rising temperature, poor soil health, hydrological imbalance are believed to have led to increasing incidence of pest diseases and abiotic stresses. Plantations of *Dalbergia sissoo* and *Acacia nilotica* are the most adversely affected by this mortality scenario[15,45]. Kaushik[29] opined that disease problems in natural forests remain under control due to genetic diversities and presence of biological antagonists. However, at the sites raised outside the forest areas (on farm lands, along road, railways, rivers, canals and panchayat lands) the trees are also exposed to varied type of biotic and abiotic stress factors which ultimately lead to increasing incidence of mortality. As the geographical domains of the problems of tree mortality are wide spread, it is unlikely that the causes, both biotic as well as abiotic, are the same everywhere and their remedies should be looked in a location specific context.

2. Plant responses of trees under salinity

2.1 The phenomena of tree mortality

Premature death of trees due to one reason or the other should not be considered to be surprising and rare phenomena in nature. The indo-gangetic plain with its expanse ranging from Burma in the east to Afghanistan in the west has been the natural habitat to a number of trees since times immemorial. These include *Acacia nilotica, Dalbergia sissoo, Prosopis cinneraria*, *Azadirachta indica, Casurina* etc. More recent introductions like *Eucalyptus, Prosopis juliflora* etc. have also naturalized with the land scape. However, in the present day changing climate scenario the past few decades have seen a strange phenomena of ‘tree mortality’ in the northern past of the Indian sub-continent comprising of the states of Punjab, Haryana, Rajasthan, Uttar-Pradesh and even adjoining Pakistan, Nepal and Myanmar. This is perceived by the contemporary foresters as a distinct ‘tree mortality’ phenomenon. Alarmed by its severity specific national and international level symposia on ‘tree mortality’ have been held in the year 2000 at Kathmandu[1] and in 2007 at Hisar[45]. As the geographic domains this problem of tree mortality are very wide spread it is, therefore, unlikely that the causes of this phenomenon are the same everywhere. It would be prudent, therefore, that the problem and its remedies should also be looked in a location specific context.

The gravity of the situation can be realized from various mortality reports. Shisham mortality in Uttar-Pradesh was 60 % in Hasanpur and Baghalkand Bhankatwa[56], 12 % in Piplee Block[47], 20 to 30 % in Ganganagar Patian Tarai[3]. Again in Bihar Dayaram *et al*.[13], reported that shisham mortality was 80 % in Areia, 78 % in Kaither, 35 % in Darbhanga, 41 % in Khageria. Likewise Parandiyal reported 3-90 % shisham mortality in Tarai central, 20 to 67 % in Tarai west, 15-22 % in Hardwar and 5-10 % in Dehradun in Uttaranchal state.

Haryana State Forest Department has reported large scale mortality of shisham and kikar in different years: 1.26,000, trees in 1997-1998, 2, 01,000 trees in 1998-99 and 2, 64,000 trees in 1999-2000[11].

During mortality various types of symptoms have been reported in the literature. Singh *et al*.[55], reported that the trees do not show any symptoms during initial stages later on exhibit gradual yellowing of leaves and fall prematurely leaving the branches bare. The leafless branches in the crown give a stag head appearance. At later stages, the fruiting bodies of the pathogen appear in lower portion of the stem or on the roots.

On the other hand Kaushik *et al*.[29], described disease symptoms in naturally wilting trees. Green trees showed sudden wilting tendency with complete leaf dropping and drying from top of tree. After 15-20 days dried leaves fell from the branches. The branches started drying from the top and the entire plant dried within 3 months. Sometimes after leaf fall, new small leaves and some new shoots emerged. However, after 3-4 months wilting reappeared. In some cases, the green leaves turned yellow and branches dried slowly from top to bottom and showed complete drying in 9-12 months. Sometimes partial wilting occurred and the healthy plant remain alive for a longer period. It took normally 2-3 year for complete plant death.

Sharma *et al*. [52], enlisted visual symptoms of different agro forestry species under salinity stress. At salinity level 3.5 dS/m *D. sissoo* and *D. latifolia* showed leaf chlorosis along with stunted root growth and in *Gmelina arborea* severe leaf necrosis along with stunted root growth was observed. At salinity level 6.5 dS/m, complete destruction of shoot and root system occurred in *D. sissoo, D. latifolia and G. arborea,* while other tree species, *Acacia nilotica, Azadirachta indica, Leucaena leucocephala, Prosopis cinerea and Prosopis juliflora* showed normal growth with reduction in number of leaves, shoot and root length.

2.2 Biotic factors and tree mortality

According to Kaushik[29] the major biotic factors that cause tree mortality include fungi, bacteria, viruses, mycoplasma, nematodes and phanerogamic parasites. Amongst these maximum obvious damage is caused by the fungal pathogens and therefore these have been studied in detail. Root rots (*Ganoderma lucidum, Botryodiplodia theobromae, Rosellinia necatrix*) and wilt *(Fusarium spp.*) are the important diseases prevalent in social and agro forestry plantations in northwestern part of the country.

Sharma *et al*. [53],observed that *Dalbergia sissoo* mortality in natural forests, plantations, roadsides and agricultural fields in India was caused by diseases (*Fusarium* wilt disease, root rot caused by *Ganoderma lucidum*, root rot caused by *Phellinus gilvus* and root rot caused by *Meloidogyne javonica*). Insect species like *Plecoptera reflexa* and *Dichomeris eridantis* also damaged *D. sissoo.*

More detailed description of the fungi and insect pests, that cause tree mortality is very exhaustive topic and beyond the scope of this review.

2.3 Abiotic factors and tree mortality

Sharma *et al*.[53], who considered biotic factors for tree mortality also emphasized that the non-biotic component of any given environment, particularly the edaphic factors, should also be taken in to consideration.

Bakshi *et al*.[3], reported that in Karnal Forest Division (Haryana) 110 ha of sissoo plantation were raised in 1952-1960 and irrigated up to 1963. The irrigation was done by shallow channels which led to the formation of superficial root system. In nine out of eleven coupes the irrigation was stopped after 1963. Mortality started after three years in all the nine coupes where the irrigation was stopped as the superficial root system was unable to draw water from lower soil depths.

Nautiyal[46] noted that the common experience was that sissoo thrives well on loose sandy soils due to proper soil aeration and good drainage, but suffers adversely in stiff and clayey soils. Soils with heavy texture and prolonged water logged condition cause asphyxiation of the roots, killing of tender roots and colonization of the dead roots by fungi.

Although, the mean temperature in last 100 years has increased by less than 1˚C which is not very high but definitely the untimely fluctuations in maximum and minimum temperatures may be the cause of metabolic disturbances which could untimely lead to the death of the trees. This view is supported by many workers as in recent years not only shisham but kikar is also dying at a fast speed specially in drier parts of the country. It may be linked with the temperature extremes noticed generally in recent years specially in plain areas[46].

2.4 Salinity and vegetative growth

According to Garg and Gupta[18]. the retardation of vegetative growth is the most common effect of salinity. As salt concentration increases there is a progressive decrease in the growth rate as well as overall size of most of the plant species. In plants where the harvestable yield is composed of vegetative parts such as the forage crops, or in plants such as maize where yield is strongly linked with vegetative dry matter production, yields are generally reduced in proportion to the decrease in plant size[7]. In case of wheat, barley and pearl millet tillering is drastically reduced. Under condition of severe salinity these tillers may die before they are able to grow and bear ears and only main shoot produces grains. The reduction in leaf area by increasing salinity is a common feature which affects plant productivity by reducing the rates of total photosynthesis by the crop canopy (McCree 1986).

Sharma *et al*.[51], observed that the order of performance of certain trees under saline conditions was: *Azadirachta indica, Dalbergia latifolia, Prosopis cineraria, Prosopis juliflora.* The maximum number of leaves and root length was observed in *Prosopis juliflora* whereas *Leucaena leucocephala* registered maximum shoot length. *Dalbergia latifolia* registered minimum number of leaves and shoot length whereas *Gmelina arborea* registered minimum root length. The reduction in the number of leaves/plant and shoot and root length under 2.5, 3.5 and 6.5 dS/m salinity levels as compared to control condition was 19.01, 47.17 and 63.66 per cent, 27.37, 52.15 and 70.71 per cent and 18.65, 42.43 and 62.86 per cent respectively.

We shall now enlist few examples of the retarding effects of salinity on tree growth. Ashraf *et al*.[2], conducted a study to evaluate the performance of some local and exotic trees, belonging to *Acacia* species, in salt affected soils of Pakistan. Five species of Acacia, i.e., *Acacia ampliceps, A. stenophylla, A. machonochieana, A. sclerosperma,* and *A. nilotica* were grown in a field where salinity ranged from 4 to 25 dS m^{-1}. After three years of growth, *A. ampliceps and A. nilotica* showed markedly higher growth as compared with the other species examined. Although *A. ampliceps* grew well under saline environment, its maximum growth was observed under low to medium salinity patches (4-12 dS m^{-1}) showing survival percentage 80-90 %. However, at high salinity (12-16 dS m^{-1}) the percent survival of *A. ampliceps* was 50 %.

Kumari *et al*.[32], observed the effect of chloride-and sulphate-dominated salinity on *A. nilotica* during germination and early growth. Salinity of both the types significantly inhibited germination and growth in *A. nilotica*. However, chloride dominated salinity was found to be more deleterious. The germination percent decreased to half at lowest (4 dS m^{-1}) level of chloride dominated salinity. At 16 dS m^{-1}, the decrease was 90%. Similarly, growth characters such as root, shoot length, dry weight at all the stages (i.e., 28 days and 4-12 months) were also affected more in chloride dominated salinity. The decrease in plumule, radical length of seedlings at 4 dS m^{-1} was 50-60% in chloride dominated salinity, whereas in sulfate dominated salinity there was slight increase in these characters at lower level and the decrease was 50% at highest level. At later seedling stages (4, 8 and 12 months), the effect of both the types of salinities was less on all of the growth characters. However the chloride dominated salinity caused more reduction even at the lowest level. Hence, in *A. nilotica* salinity of both the types was more deleterious at germination and early seedling stage as compared to later grown stages.

Hussain and Alshammary[27] conducted a 20-week-long greenhouse experiment to determine the effect of salinity on the survival and growth of landscape trees and soil properties. The survival period of trees decreased significantly with an increase in soil salinity resulting from irrigation water salinity. The survival period of *Acacia nilotica* and *Prosopis juliflora* was significantly more than *Eucalyptus camaldulensis* and *Parkinsonia aculeate* under different water salinity levels and soil types. The total biomass decreased significantly with an increase in soil salinity. Soil salinity and sodicity increased significantly with increasing irrigation water salinity and sodicity. *P. juliflora* tolerated soil salinity (ECe) up to 39.5 dS m^{-1} and *A. nilotica* up to 44.9 (ECe) when irrigated with water salinity of 12.80 dS m^{-1}; *P. aculeate* up to 29.26 (ECe) when irrigated with water salinity of 6.45 dS m^{-1}; and *E. camaldulensis* up to

34.3 (ECe) when irrigated with water salinity of 6.45 dS m^{-1}.

Qing *et al*.[48], observed that with the increase in salinity from 6 dS m^{-1} to 9 dS m^{-1} height of three hybrid poplars declined. The tree heights of Qing Shan Yang merely declined 20%, and were less than hybrid Zhong Hei Fang and hybrid Xiao Hei 14.

Khan *et al*. [30], described the effect of salinity on growth of some forest trees at their seedling stage. Four forest tree species i.e. *Acacia ampliceps, Acacia nilotica, Eucalyptus camaldulensis* and *Azadirachta indica* were tested against 3.61, 6.0, 12 and 18 dS/m ECe levels. Length of root, shoot and root shoot ratio of these forest species were significantly affected by salinity. Moreover growth parameters of each forest tree species decreased as salinity increased.

3. Salinity and plant water relations

It is well recognized that dissolved solutes in the root zone generate a low osmotic potential that lowers the soil water potential. The general water balance of plants is thus affected, because the shoot needs to have even lower water potential to maintain a "downhill" gradient of water potential between the soil and leaves[59]. Further salinity effects depend not only on water balance but the nature and degree of the effects also depend on climatic conditions and may vary between plants species and in the same species at different periods of growth[16]. Under salt-stress conditions, decrease in the water availability to the plant has been observed[8,26,34]. Regulation of tissue solute concentrations, generally termed as osmotic adjustment has been considered as an important mechanism by which higher plants can adapt to increasing soil salinity[22]. However, degree of osmotic adjustment varies within crop species, cultivars and types of salinity[41,25,31]. It was also suggested that osmotic adjustment might itself be responsible for inhibition of growth due to diversion of energy from growth function to osmotic adjustment and tissue reparation mechanisms.

Salt ions in high concentration cause a physiological non-availability of water to the roots of plants and adversely affect the water balance leading to growth suppression. Many workers observed reduction in water content and osmotic potential in plant tissue under salt-stress[14,23,21,57,12]. The decrease in tissue osmotic potential is responsible for maintenance of turgor pressure by plants under stress conditions. Stephan and Thorpe [57]. reported decreased water content and osmotic potential of *Brassica* callus under salt stress. Similarly, Walker and Dumbroff [60] observed decreased water content and osmotic potential in tomato leaves. In addition, Chandler and Thorpe[10] found more negative water potential in calli of *Brassica napus* grown under sodium chloride salinity than that of sodium sulphate salinity and more negative in salt sensitive as compared to salt-tolerant callus.

Lowering of osmotic potential as the water decreases has been attributed to the accumulation of a wide range of solutes and thus, maintaining the turgor potential of the tissue. Weimberg[61] described that accumulation of solutes in two wheat cultivars took place only on exogenous application of sucrose or potassium chloride or sodium chloride. Bernstein[5,6] and Levner and Poljakoff-Mayber[35] demonstrated the occurrence of osmotic adjustment under salt-stress due to either accumulation of organic solutes or salt-ions and claimed that growth inhibition by salinity, cannot be attributed solely to water stress in the sense of lower plant turgor, but process of osmotic adjustment itself is a limiting factor for growth.

Maliwal and Sutaria[37], demonstrated an increase in osmotic pressure of leaf cell sap with increasing salt stress in wheat. Sharma *et al*.[54], found decreased relative water content, water potential and osmotic potential of leaves in wheat grown under saline environment, while, decline in relative water content in the leaves of salt stressed barley plant was reported by Nakamura *et al*.[44]. Rodriguez *et al*.[50], observed that salt-shock caused decrease in root water potential and solute potential with a minor change in turgor potential in root of maize.

Nabil and Coudret[43] observed that *Acacia nilotica* subjected to NaCl stress showed decreased water potential and osmotic pressure with salinity and concluded that lower water potential enabled the plant to maintain the turgor.

Mehari *et al*.[40], compared the salt tolerance of *Acacia tortills* and *Acacia nilotica*. Although the two species didn't differ in their sensitivity to salinity, there was significant variance in shoot water in response of increase NaCl salinity between the two species.

Kumari and Toky[33]. observed that reduction in growth under salinity in *Acacia nilotica* was accompanied by in the decline in relative water content, leaf water potential and osmotic potential.

4. Effect of salinity on leaf pigments

Workers dealing with salinity effects on leaf pigments particularly chlorophyll, have reported different kind of trends. Several workers have found that salinity decreases chlorophyll content of plants. Garg and Garg[17], Garg and Lahiri[19] observed that salinity generally reduced chlorophyll content in a number of crop plants such as pearl millet, cluster bean, mung bean and Indian mustard. On the other hand interesting data are provided by Strognov[58] who found a marked increased in both chlorophyll 'a' and 'b' under saline condition in a number of plants. Increased chlorophyll content in saline habitats has been found in tomatoes, cotton and other glycophytes.

Similar reports in tree species are also found in literature. Rawat and Banerjee[49] found that NaCl salinity causes the decline of protein and chlorophyll concentration in *Eucalyptus camaldulensis* and *Dalbergia sissoo* plants.

Mazher *et al*.[38] found that *Dalbergia sissoo* seedling irrigated with saline water showed a decrease in the content of chlorophyll a, b and carotenoids as well as growth parameters. However, application of sulphur caused an increase in the pigment contents and nutrients like N, P and K and improved growth. Qing *et al*.[48], studied growth and physiological adaptability of three poplars planted in different saline alkali soil. The find that saline alkali soil chlorophyll content was less affected though the annual mean decreases slightly. Zhen *et al*.[62], found that when salinity concentration increased physiological indexes, including chlorophyll content, photosynthetic rate, stomatal conductance and the transpiration rate increased at first and then decreased. The range of change in order was: *Rosa chinensis*, *Morus alba* and *Rhaphiolepis umbellata*. Salt-tolerance of *Rhaphiolepis umbellata* was the highest, followed by *Morus alba* and *Rosa chinensis.* In *Acacia nilotica* chlorophyll content of leaves declined with the increase in salinity in seedlings representing ten Indian provenances. The decrease was more in sulphate-dominated salinity as compared with chloride-dominated salinity[33].

5. Soil salinity and mineral nutrition

Reduced growth and development under saline environment is due to deficiency of essential nutrients as well as due to excess of salt ions. Under saline conditions the salt ions competitively reduce the uptake of nutrients due to which the plants face the situation of deficiency of elements which are essential for growth and development. Typically under salt stress, with NaCl as the predominant salt, accumulation of Na and Cl along with reduced uptake of K, P and NO_3 has been reported in several crop plants[18]. Selected reports on this aspect in tree species are reviewed here.

Bimlendra and Datta[9] reported that increase in the salt ions and decrease in nutrient ions in leaves, stem as well as roots is associated with salinity in *Acacia nilotica*. Thus reduction was observed in content of N, P, K and Ca but the content of Na, Mg, SO_4 and Cl increased under saline conditions in leaves, stem, and root.

Giri *et al.*[20], observed that in *Acacia nilotica* salinity level in the range of 6.5 and 9.5 dS m^{-1} increased Na concentration but decreased K and P concentration. However, *Acacia nilotica* plants associated with arbuscular mycorrhiza, *Glomus fasiculatum* showed better vegetative growth, which could be correlated with relatively lower Na and increased K and higher P in the shoots. The authors also concluded that the improved K/Na ratios in root and shoot tissue of mycorrhizal plants may help in protecting disruption of K-mediated enzymatic processes under salt stress conditions.

Michael *et al.*[42], experimenting with three rootstocks of Avocado trees concluded that Cl concentration and Na: K ratio in older leaves was a useful marker for salinity tolerance screening in Avocado rootstocks. The relative tolerance of various rootstocks appeared to be primarily due to their ability to exclude Na and Cl from the leaves.

Hardikar and Pandey[24] observed that NaCl salinity caused many fold net uptake of Na in the shoot tissues of *Acacia senegal*. At the same time N, P, K and Ca content decreased significantly in response to salinity K /Na ratio decreased significantly with increase in salt stress. Microelements Zn, Cu, Mg, and Fe were also found to decrease under salt stress.

Populas alba plants were subjected to low NaCl treatment (2000 mg/L) or high NaCl (5000 mg/L) treatments. Results showed that high treatment plants had 20 percent mortality and about twice the level of Na in dead leaves and branches as compared to the low salt concentration[28].

Ma *et al.*[36], observed that salt resistant *Populas euphratica* had a higher ability to retain lower NaCl concentration in the cytoplasm due to sustained activity of H^+ pumps as compared to the salt sensitive *P. popularis.* The inability of *P. popularis* to transport salt to the apoplast and vacuole was partly due to the decreased activity of membrane H^+ pumps. As a consequence, cytosolic ion concentrations were observed to be comparatively high for an extended period of time, so that cell metabolism, in particular respiration, was disrupted in *P. popularis* leaves.

CONCLUSION

Considered in totality it would appear that the salinity in the soil profile has a perpetual retarding effect on various physiological and biochemical parameters of *Dalbergia sissoo* as well as *Acacia nilotica*. This alone or in combination with other abiotic and biotic factors may lead to a slow decline and ultimate mortality of the trees.

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